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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 926 059 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
30.06.1999 Bulletin 1999/26

(51) Int. Cl.[6]: B62M 23/02

(21) Application number: 98310636.0

(22) Date of filing: 23.12.1998

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 24.12.1997 JP 35442997
28.05.1998 JP 14715098

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(54) Vehicle with power assist unit and controlling method therefor

(57) In a vehicle (1) with power assist unit (3) and a controlling method for the same of the present invention, an acceleration calculation unit (8) calculates an acceleration in a reference environment in the case where the vehicle runs in the reference environment on the basis of a human drive force from a human drive power detection unit, a speed from a speed detection unit (6a), and preset various reference parameters in the reference environment from a reference environment setting unit. Furthermore, an assist ratio determination unit compares the current acceleration with the acceleration in the reference environment supplied from the acceleration calculation unit and then determines an assist ratio on the basis of the result of the comparison.

FIG. 1

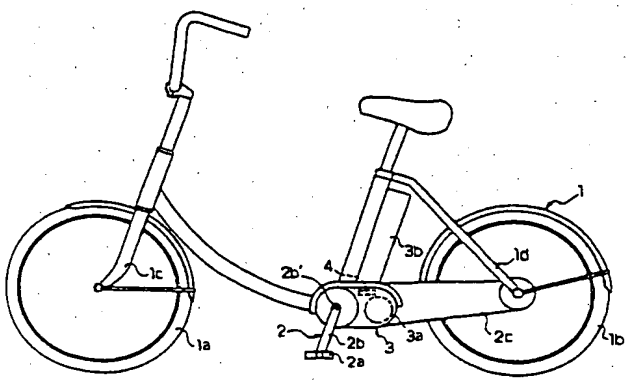

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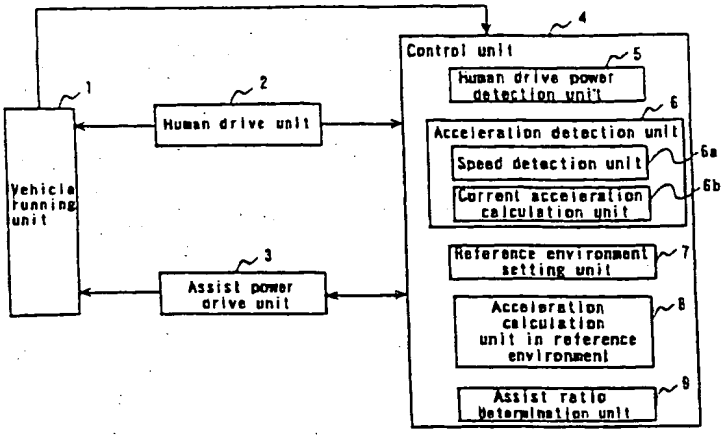
FIG. 2


Control unit
4
5
Human drive power detection unit
6
Acceleration detection unit
Speed detection unit
6a
Current acceleration calculation unit
6b
Reference environment setting unit
7
Acceleration calculation unit in reference environment
8
Assist ratio determination unit
9
1
Vehicle running unit
2
Human drive unit
3
Assist power drive unit

Description

[0001] The present invention relates to a vehicle with power assist unit which is driven by using human power and assist power from the power assist unit, and a controlling method for the same.

[0002] Recently, a vehicle with power assist unit has been developed to include a known drive device, such as an electric motor, as a power assist unit, and driven by assist power from the power assist unit applied in addition to a force (hereinafter referred to as a "human drive power") based on human power by an operator, a user or the like. Specific examples of such vehicles are a bicycle with the motor, a wheelchair with the motor, a cargo carrier with the motor and the like. In this kind of vehicle, assist power generated by the motor is added over a rotation power generated by pressing pedals or a rotation power generated by rotating hand rims of wheels. This type of vehicle with power assist unit are driven by always adding the assist power to the human drive power with a certain ratio (hereinafter referred to as an "assist ratio").

[0003] For example, a bicycle with electric motor has been disclosed in Japanese Laid-open Patent Application No. Hei 6-255564 as a first conventional vehicle with power assist unit. This first conventional vehicle with power assist unit is provided with a motor output calculation unit which measures human drive power in one period of motion cycle and then determines an average electric motor output (or an average torque) for the next period on the basis of the value of the measurement. The first conventional vehicle with power assist unit is also provided With an output control unit for generating the obtained motor output. In other words, in the first conventional vehicle with power assist unit, the output torque of the electric motor is controlled by responding in each period of a change in the detected human drive force, thereby to drive the vehicle.

[0004] However, the first conventional vehicle with power assist unit is configured to add assist power having a constant assist ratio for the human drive power responding in each period of a change in the detected human drive power to the human drive power without regard for running resistances corresponding to road surface and meteorological conditions. For this reason, in the first conventional vehicle with power assist unit, it was impossible to drive its wheels appropriately responding with change of the running resistances.

[0005] As a second conventional vehicle with power assist unit, an assist power control method for a power-assisted bicycle and an apparatus for the same have been disclosed in Japanese Laid-open Patent Application No. Hei 8-99683. This second conventional vehicle with power assist unit is provided with a speed sensor for detecting vehicle speed and a sensor for detecting acceleration of the vehicle and inclination angle of road surface. In the second conventional vehicle with power assist unit, the amount of work due to the bicycle is estimated on the basis of the detected speed and acceleration or inclination angle. With this configuration of the second conventional vehicle with power assist unit, the output torque of the electric motor is determined on the basis of the estimated human drive power without directly detecting the human drive power.

[0006] However, in the second conventional vehicle with power assist unit, it was impossible to detect change of the running resistances. For this reason, just as in the case of the first conventional vehicle with power assist unit, the second conventional vehicle with power assist unit cannot appropriately drive its wheels responding with the change of the running resistances.

[0007] As described above, in the conventional vehicles with power assist units, the assist ratio cannot be changed or determined to an optimal value in response to the change of the running resistances because the assist power is determined responding with the human drive power and the amount of work thereof. Therefore, an assist ratio suited for a running environment cannot be determined in the case of the conventional vehicles with power assist units, and an excessive burden or too much assist power were imposed on the operator or user. This results in lowering the ride comfort of the vehicle (bicycle) in the conventional vehicle with power assist unit.

BRIEF SUMMARY OF THE INVENTION

[0008] The object of the present invention is to provide a vehicle with power assist unit and controlling method for the same that can solve the aforementioned problems in the conventional vehicle with power assist unit and controlling method for the same, can be configured with less cost and has a long life.

[0009] In order to achieve the above-mentioned object, a vehicle has power assist unit including a vehicle running unit for running the vehicle, a human drive unit for supplying a human drive power to the vehicle running unit and an assist power drive unit for supplying assist power to the vehicle running unit, and,

the vehicle comprises:

a human drive power detection unit for detecting a human drive force,

an acceleration detection unit for detecting the speed and the acceleration of said vehicle,

a reference environment setting unit for presetting various reference parameters in a reference environment wherein the vehicle runs,

an acceleration calculation unit in the reference environment for calculating an acceleration in the reference environment in the case where the vehicle runs in the reference environment on the basis of the human drive force from the human drive power detection unit, the speed from the acceleration detection unit and the parameters in the reference environment from the reference environment setting unit, and

an assist ratio determination unit for determining the assist ratio of the assist power drive unit to the human drive unit on the basis of the acceleration from the acceleration detection unit and said acceleration in the reference environment from the acceleration calculation unit.

[0010] With this configuration of the vehicle with power assist unit of the present invention, it is possible to determine an assist ratio suited for a running environment responding with change of running resistances. As a result, the vehicle can be driven appropriately. Consequently, the vehicle can run naturally and smoothly without excessive burden and too much assist power on an operator or the like with respect to the ride comfort and performance of the vehicle.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0011]

FIG. 1 is an overall view showing a general configuration of a vehicle with power assist unit of a first embodiment of the present invention.

FIG. 2 is a block diagram showing the configuration of the vehicle with power assist unit shown in FIG. 1.

FIG. 3 is a graph showing an example of a human drive force detected by a human drive power detection unit shown in FIG. 2.

FIG. 4 is a graph showing a relationship between an acceleration and a human drive force obtained by an acceleration calculation unit in a reference environment shown in FIG. 1.

FIG. 5 is a flowchart showing the operation of the vehicle with power assist unit shown in FIG. 1.

FIG. 6 is a block diagram showing the configuration of a vehicle with power assist unit of a second embodiment of the present invention.

FIG. 7 is a block diagram showing a method of determining an assist ratio for the vehicle with power assist unit shown in FIG. 6.

FIG. 8 is a flowchart showing the operation of the vehicle with power assist unit shown in FIG. 6.

FIG. 9 is a block diagram showing the configuration of a vehicle with power assist unit of a third embodiment of the present invention.

FIG. 10 is a flowchart showing the operation of the vehicle with power assist unit shown in FIG. 9.

DETAILED DESCRIPTION OF THE INVENTION

[0012] Preferred embodiments of a vehicle with power assist unit and controlling method for the same of the present invention will be described with reference to the accompanying drawings. In the following descriptions, a bicycle driven by a leg power (a pedal pressing power) in combination with an assist power will be described as a preferred embodiment of the vehicle with the power assist unit of the present invention. A wheelchair is realized as the other embodiment.

First embodiment

[0013] FIG. 1 is an overall view showing a general configuration of a vehicle with power assist unit of a first embodiment of the present invention. FIG. 2 is a block diagram showing the configuration of the vehicle with power assist shown in FIG. 1.

[0014] As shown in FIGs. 1 and 2, a vehicle with power assist unit of the present embodiment comprises a vehicle running unit 1 for running the vehicle, a human drive unit 2 and an assist power drive unit 3 for assistingly driving the vehicle running unit 1, and a control unit 4 for controlling the assist power drive unit 3.

[0015] The vehicle running unit 1 is provided with wheels 1a and 1b rotatably making contact with a road surface to allow the vehicle to run, and support mechanisms 1c and 1d for rotatably supporting the wheels 1a and 1b, respectively. A human drive power from the human drive unit 2 and an assist power from the assist power drive unit 3 are supplied to the vehicle running unit 1. As a result, the wheels 1a and 1b are rotated by total powers, and the vehicle runs.

[0016] The human drive unit 2 includes pedals 2a for receiving a human drive power from an operator or a user, and a transmission mechanism 2c comprising a pedal crank 2b, a chain, and a one-way clutch for transmitting the human drive power to the vehicle running unit 1 as the human drive force. Furthermore, the transmission mechanism 2c may be configured with use of a shaft drive.

[0017] The assist power drive unit 3 includes a known drive unit 3a such as an actuator having an electric motor, and a battery 3b such as a secondary battery used as an electric power supply for the drive unit 3a. The drive unit 3a is activated (rotated) on the basis of an instruction signal from the control unit 4. Furthermore, output of the assist power drive unit 3 is transmitted as the assist power to the vehicle running unit 1 via the transmission mechanism 2c. A transmission mechanism for the assist power drive unit 3 is configured with a common mechanism for the human drive unit 2, and alternatively configured with an exclusive mechanism.

[0018] The control unit 4 includes a human drive power detection unit 5 for detecting the human drive force Fh transmitted from the human drive unit 2 to the vehicle running unit 1. The control unit 4 further includes an acceleration detection unit 6 for detecting a current acceleration α_1 of the vehicle, and a reference environment setting unit 7 for presetting various references parameters in a reference environment described later. In addition, the control unit 4 includes an acceleration calculation unit 8 for calculating acceleration α_0 in the reference environment of the vehicle. The control unit 4 further includes an assist ratio determination unit 9 for determining a ratio Q (hereinafter referred to as an "assist ratio") of the assist power to the detected human drive force on the basis of the acceleration α_0 in the reference environment and the current acceleration α_1.

[0019] The human drive power detection unit 5 is formed of a torque sensor, and detects the human drive force Fh, which is proportional to the human drive power, in a predetermined time period (1 msec for example). The human drive power detection unit 5 outputs the detected human drive force Fh to the acceleration calculation unit 8 and the assist ratio determination unit 9. The torque sensor is herein defined as a non contact sensor which can detect the human drive force Fh transmitted from the human drive unit 2 to the vehicle running unit 1 as a torque without making connection to a member of the human drive unit 2, such as a crankshaft 2b', via a mechanical member or a wire, or without making sliding contact. More specifically, a magnetic-distortion torque sensor comprising a belt-like magnetic film for generating a distortion in response to a change in the human drive force Fh applied to the pedal crank 2b and a coil for detecting a change in magnetic permeability due to the distortion is taken as an example of the non-contact torque sensor. Instead of the non-contact torque sensor, another torque sensor is also available which comprises a spring disposed between the crankshaft 2b' and a drive sprocket (not shown), and detects a torque by detecting a strain generated in the spring by using an optical encoder or a Hall-effect device.

[0020] The human drive force Fh detected by the human drive power detection unit 5 pulsates in response to the rotation of the pedal crank 2b as shown by a curve 31 shown in FIG. 3. The period of the pulsation is inversely proportional to the rotation speed of the pedal crank 2b. For this reason, when the pulsating human drive force Fh is used, the assist ratio is changed frequently, whereby the ride comfort of the vehicle may be lowered. To solve this problem, it may be possible to have a configuration wherein the human drive power detection unit 5 calculates the average value of a plurality of continuously detected human drive force values, and outputs the average value to the acceleration calculation unit 8 and the assist ratio determination unit 9. Furthermore, it may also be possible to have a configuration wherein the maximum value of the human drive force detected in one period is multiplied by a predetermined value ($1/\sqrt{2}$ for example) and output to the acceleration calculation unit 8 and the assist ratio determination unit 9. With these configurations, the change in the assist ratio Q becomes smooth, and it is possible to prevent the ride comfort of the vehicle from being lowered.

[0021] The acceleration detection unit 6 comprises a speed detection unit 6a for detecting the current speed V of the vehicle, and an acceleration calculation unit 6b for calculating the current acceleration α_1 on the basis of the detected speed V. The speed detection unit 6a is formed of a mechanical-optical type or electromagnetic type encoder for example, and outputs the detected speed V to the acceleration calculation unit 6b and the acceleration calculation unit 8 in the reference environment.

[0022] Instead of the configuration described above, it may be possible to have a configuration wherein the acceleration detection unit 6 calculates the period of the human drive force Fh by using the human drive force Fh from the human drive power detection unit 5, and then calculates the speed V and the acceleration α_1 of the vehicle. With this configuration, no speed sensor is required to be used.

[0023] The reference environment setting unit 7 is used to preset reference environment parameters required for calculating an acceleration in an estimated reference environment including road surface and meteorological conditions. Specific reference environment parameters are the inclination angle θ of a road surface and running resistance d exerted on the vehicle. The running resistance d is stipulated in accordance with the above-mentioned inclination angle θ, a kinetic friction force from the road surface, air resistance due to meteorological conditions such as wind, etc.

[0024] The acceleration calculation unit 8 calculates acceleration α_0 in the reference environment when the vehicle runs therein. This calculation is carried out on the basis of the human drive force Fh from the human drive power detection unit 5, the speed V from the speed detection unit 6a and the reference environment parameters (the inclination angle θ and the running resistance d) preset by the reference environment setting unit 7. More specifically, the acceleration calculation unit 8 calculates the above-mentioned acceleration α_0 by using the following equation of motion (1) for the vehicle, and outputs the acceleration α_0 to the assist ratio determination unit 9.

$$m \times \alpha + d \times V + m \times g \times \sin\theta = Fh + Q \times Fh \quad \text{--- (1)}$$

[0025] In the equation (1), m is the overall weight of the vehicle including the standard weight of the operator (60 kg for example), and g is the gravitational acceleration. The overall weight m and the gravitational acceleration g have been set beforehand in the acceleration calculation unit 8. Instead of use of the standard weight, it may be possible to use a detected weight of the operator with a load sensor. The second term on the right side of the equation (1) represents the assist power of the assist power drive unit 3. A predetermined initial value has been set as the assist ratio Q.

[0026] By substituting the reference environment parameters, the initial value of the assist ratio Q, the speed V and the human drive force Fh into the equation (1), the relationship between the acceleration α_o and the human drive force Fh in the reference environment shown by a linear line 41 in FIG. 4 is obtained in the acceleration calculation unit 8 for example.

[0027] The assist ratio determination unit 9 compares the current acceleration α_1 from the acceleration detection unit 6 with the acceleration α_o in the reference environment from the acceleration calculation unit 8. In the case when the current acceleration α_1 is larger than the acceleration α_o in the reference environment, that is, in the case where the current acceleration α_1 is located in an area above the linear line 41 shown in FIG. 4 she assist ratio determination unit 9 Judges that the initial value of the assist ratio Q is excessive for the current running environment. The assist ratio determination unit 9 then decreases the initial value of the assist ratio Q by a preset predetermined value. As a result, an instruction signal for decreasing the assist ratio Q is delivered from the control unit 4 to the assist power drive unit 3.

[0028] On the other hand, in the case when the current acceleration α_1 is smaller than the acceleration α_o in the reference environment, that is, in the case where the current acceleration α_1 is located in an area below the linear line 41 shown in FIG. 4, the assist ratio determination unit 9 judges that the initial value of the assist ratio Q is insufficient for the current running environment. The assist ratio determination unit 9 then increases the initial value of the assist ratio Q by the preset predetermined value. As a result, an instruction signal for increasing the assist ratio Q is delivered from the control unit 4 to the assist power drive unit 3.

[0029] As described above, the assist ratio determination unit 9 of the present embodiment can determine an assist ratio suited for a running environment responding with change of the running resistances. As a result, the vehicle can be driven appropriately.

[0030] Instead of the above-mentioned configuration, it may be possible to have a configuration wherein the assist ratio Q is zero in the case when the value of the human drive force supplied from the human drive power detection unit is zero. With this configuration, the vehicle can run safely. Furthermore, it may be possible to have a configuration wherein a sensor is provided to detect the operation angle of a brake lever operated by the operator, and the assist ratio determination unit 9 sets the assist ratio Q to zero when the operation angle becomes a predetermined angle or more.

[0031] By setting d = 0 in the above-mentioned equation (1), a running environment wherein the running resistance d is almost zero can be used as the reference environment. Furthermore, instead of the initial value, a value at the present time may be assigned to the assist ratio Q and substituted into the equation (1). Moreover, responding with a ratio between the acceleration α_o in the reference environment and the current acceleration α_1, the assist ratio Q may be calculated for each ratio. Besides, even when a value is preset, it may be possible to carry out a method wherein plural setting values other than the initial value may be ready for use as the assist ratio Q, and may be selectively used appropriately as necessary.

[0032] Apart from the aforementioned explanation, wherein the assist ratio Q is changed by the preset predetermined value, an alternative configuration may be such that various values say be calculated for each ratio responding with the ratio of the acceleration α_o in the reference environment and the current acceleration α_1. In addition, even when the preset predetermined value is used, it may be possible to carry out a method wherein plural predetermined values may be ready for use, and may be selectively used appropriately.

[0033] Furthermore, instead of using the equation of motion (1) for the vehicle, the equation (1) may be modified. For example, a term proportional to the square of the speed may be added to the equation (1). Moreover, it may be possible to have a configuration wherein an input device such as a numeric keypad may be provided so that the operator can change the overall weight m, the running resistance d or the inclination angle θ.

[0034] Operation of the vehicle with power assist unit will be described below referring to FIG. 5.

[0035] FIG. 5 is a flowchart showing the operation of the vehicle with power assist unit shown in FIG. 1.

[0036] As shown in FIG. 5, in the vehicle with power assist unit of the present embodiment, the human drive power detection unit 5 detects the human drive force transmitted from the human drive unit 2 to the vehicle running unit 1 in the first place (step S1). After this, the human drive power detection unit 5 outputs the detected human drive force to

the acceleration calculation unit 8 in the reference environment and the assist ratio determination unit 9 (step S2).

[0037] Next, the acceleration calculation unit 8 calculates acceleration α_o in the reference environment based upon the human drive force Fh from the human drive power detection unit 5, the speed V from the speed detection unit 6a and the preset reference environment parameters (the inclination angle θ and the running resistance d) from the reference environment setting unit 7 (step S3). And then, the acceleration calculation unit 8 outputs the calculated acceleration α_o in the reference environment to the assist ratio determination unit 9.

[0038] The assist ratio determination unit 9 compares the current acceleration α_1 supplied from the acceleration detection unit 6 with the acceleration α_o in the reference environment supplied from the acceleration calculation unit 8. The assist ratio determination unit 9 then determines whether the current acceleration α_1 is larger than the acceleration α_o in the reference environment or not (step S4).

[0039] In the case when the current acceleration α_1 is larger than the acceleration α_o in the reference environment, the assist ratio determination unit 9 determines that the initial value of the assist ratio Q is excessive for the current running environment. After this, the assist ratio determination unit 9 decreases the initial value of the assist ratio Q by the preset predetermined value, and determines the obtained value as the assist ratio (step S5). As a result, an instruction signal for decreasing the assist ratio Q is delivered from the control unit 4 to the assist power drive unit 3.

[0040] In the case when the current acceleration α_1 is smaller than the acceleration α_o in the reference environment, the assist ratio determination unit 9 judges that the initial value of the assist ratio Q is insufficient for the current running environment. The assist ratio determination unit 9 then increases the initial value of the assist ratio Q by the preset predetermined value (step S6). As a result, an instruction signal for increasing the assist ratio Q is delivered from the control unit 4 to the assist power drive unit 3.

[0041] As described above, in the vehicle with power assist unit and the controlling method for the same of the present embodiment, the acceleration calculation unit 8 in the reference environment calculates acceleration α_o in the reference environment. This calculation is carried out on the basis of the human drive force Fh from the human drive power detection unit 5, the speed V from the speed detection unit 6a and the preset reference environment parameters from the reference environment setting unit 7. Furthermore, the assist ratio determination unit 9 compares the current acceleration α_1 supplied from the acceleration detection unit 6 with the acceleration α_o in the reference environment supplied from the acceleration calculation unit 8, and determines the assist ratio Q on the basis of the result of the comparison. Thereby, in the vehicle with power assist unit and the controlling method for the same of the present embodiment, it is possible to determine the assist ratio Q suited for the running environment responding with the change of the running resistances. As a result, the vehicle can be driven appropriately. Consequently, in the vehicle with power assist unit and the controlling method of the present embodiment, the vehicle can run naturally and smoothly without imposing any sense of discomfort on an operator or the like with respect to the ride comfort of the vehicle.

Second Embodiment

[0042] FIG. 6 is a block diagram showing the configuration of a vehicle with power assist unit of a second embodiment of the present invention. In the configuration of a vehicle with power assist unit of the present embodiment, an assist ratio determination unit estimates a current running environment on the basis of a detected human drive force and a detected acceleration, and determines an assist ratio. Except for this feature, the present embodiment is the same as the first embodiment, and descriptions overlapping each other are omitted.

[0043] Referring to FIG. 6, in the vehicle with power assist unit of the present embodiment; an assist ratio determination unit 11 in a control unit 10 estimates the current running environment on the basis of the human drive force Fh from the human drive power detection unit 5 and the acceleration α_1 from the acceleration detection unit 6, and determines the assist ratio. With this configuration of the vehicle with power assist unit of the present embodiment, it is possible to determine the assist ratio suited for the running environment responding with the change of the running resistances. As a result, the vehicle can be driven appropriately.

[0044] A method of determining the assist ratio by using the assist ratio determination unit 11 will be elucidated with reference to FIG. 6 and FIG. 7 more specifically.

[0045] FIG. 7 is a block diagram showing a method of determining an assist ratio for the vehicle with power assist unit shown in FIG. 6.

[0046] Referring to FIG. 6 and FIG. 7, a force R in a running environment exerted on the running vehicle is represented by using a function having the speed V of the vehicle, running resistance d, the overall weight m of the vehicle, the gravitational acceleration g and the inclination angle θ of a road surface as parameter thereof. For example, the force R is represented by the following equation (2).

$$R = d \times V + m \times g \times \sin\theta \quad \text{--- (2)}$$

[0047] The following equation (3) can be obtained from the aforementioned equations (1) and (2).

$$R = Fh + Q \times Fh - m \times \alpha_1 \quad \text{--- (3)}$$

[0048] Just as in the case of the first embodiment, the preset value including the initial value, the value at the present time or the value calculated responding with the detected current human drive force is used as the assist ratio Q in equation (3). In other words, on the basis of the human drive force from the human drive power detection unit 5, the assist ratio determination unit 11 selects one of the preset value, the value at the present time and the value calculated responding with the detected current human drive force, and determines the selected value as a first assist ratio.

[0049] In addition, since the force R in the running environment is a force exerted on the running vehicle, the force becomes a multiple of the detected human drive force, and the following equation (4) is set up.

$$R = q \times Fh \quad \text{--- (4)}$$

[0050] The following equation (5) can be obtained from the above-mentioned equations (3) and (4).

$$q = (Fh + Q \times Fh - m \times \alpha_1) / Fh \quad \text{--- (5)}$$

[0051] A second assist ratio q is calculated by substituting the human drive force Fh from the human drive power detection unit 5 and the acceleration α_1 from the acceleration detection unit 6 into the above-mentioned equation (5). The assist ratio determination unit 11 determines this second assist ratio q as a new assist ratio. Consequently, it is possible to determine the assist ratio suited for the current running environment, and the vehicle can be driven appropriately.

[0052] Furthermore, it may be possible to have a configuration wherein the value q is calculated from the following equation (6) to compensate for the inertia term of the vehicle. With this configuration, an inertia force exerted on the vehicle can be reduced, and the riding comfort of the vehicle can be improved. In the equation (6), p is a constant value determined depending on the rated output of an electric motor.

$$q = (Fh + Q \times Fh - m \times \alpha_1) / Fh + m \times \alpha_1 / p \quad \text{--- (6)}$$

[0053] Operation of the vehicle with power assist unit of the present embodiment will be described below referring to FIG. 8.

[0054] FIG. 8 is a flowchart showing the operation of the vehicle with power assist unit shown in FIG. 6.

[0055] As shown in FIG. 8, the human drive power detection unit 5 outputs the detected human drive force, and the acceleration detection unit 6 outputs the detected acceleration to the assist ratio determination unit 11 (step S7).

[0056] Next, on the basis of the human drive force from the human drive power detection unit 5, the assist ratio determination unit 11 selects one of the preset value including the initial value, the value at the present time and the value calculated responding with the detected current human drive force, and determines the selected value as the first assist ratio (step S8). After this, on the basis of the determined first assist ratio and the acceleration α_1 from the acceleration detection unit 6, the assist ratio determination unit 11 calculates the second assist ratio q, and determines the second assist ratio q as the new assist ratio Q (step S9).

[0057] As described above, in the vehicle with power assist unit and the controlling method for the same of the present embodiment, the assist ratio determination unit 11 estimates the current running environment on the basis of the human drive force Fh from the human drive power detection unit 5 and the acceleration α_1 from the acceleration detection unit 6, and determines the assist ratio. With this configuration of the vehicle with power assist unit and the controlling method for the same of the present embodiment, it is possible to determine the assist ratio suited for the running

environment responding with the change of the running resistances. As a result, the vehicle can be driven appropriately. Furthermore, in the vehicle with power assist unit and the controlling method for the same of the present embodiment, it is possible to determine the assist ratio more suited for the current running environment than that in the case of the first embodiment wherein the preset inclination angle θ and running resistance d are used as the reference environment parameters.

Third Embodiment

[0058] FIG. 9 is a block diagram showing the configuration of a vehicle with power assist unit of a third embodiment of the present invention. In the configuration of a vehicle with power assist unit of the present embodiment, an inclination angle detection unit is provided to detect the inclination angle of the road surface. An assist ratio determination unit estimates the current running environment on the basis of the detected human drive force, the detected acceleration and a detected inclination angle, and determines the assist ratio. Except for this feature, the present embodiment is the same as the second embodiment, and descriptions overlapping each other are omitted.

[0059] Referring to FIG. 9, in the vehicle with power assist unit of the present embodiment, an inclination angle detection unit 13 for detecting the inclination angle θ of the road surface is provided in a control unit 12. An assist ratio determination unit 14 estimates a current running environment on the basis of a human drive force Fh from a human drive power detection unit 5, an acceleration α_1 from an acceleration detection unit 6 and an inclination angle θ from the inclination angle detection unit 13, and determines an assist ratio. With this configuration of the vehicle with power assist unit of the present embodiment, it is possible to determine the assist ratio suited for the running environment responding with the change of the running resistances. As a result, the vehicle can he driven appropriately.

[0060] More specifically, a force R' exerted on the running vehicle due to the running resistance d is represented by the following equation (7) by using the speed V of the vehicle and the running resistance d.

$$R' = d \times V \qquad \text{--- (7)}$$

[0061] The following equation (8) can be obtained from the aforementioned equations (1) and (7).

$$R' = Fh + Q \times Fh - m \times \alpha_1 - m \times g \times \sin\theta \qquad \text{--- (8)}$$

[0062] In addition, since the force R' due to the running resistances is the force exerted on the running vehicle, the force becomes a multiple of the detected human drive force, and the following equation (9) is set up.

$$R' = q' \times Fh \qquad \text{--- (9)}$$

[0063] The following equation (10) can be obtained from the above-mentioned equations (8) and (9).

$$q' = (Fh + Q \times Fh - m \times \alpha_1 - m \times g \times \sin\theta) / Fh \qquad \text{--- (10)}$$

[0064] The assist ratio q' is calculated by substituting the human drive force Fh from the human drive power detection unit 5, the acceleration α_1 from the acceleration detection unit 6 and the inclination angle θ from the inclination angle detection unit 13 into the above-mentioned equation (10). The assist ratio determination unit 14 determines the assist

ratio q' as a new assist ratio. Consequently, it is possible to determine an assist ratio suited for a current running environment, and the vehicle can be driven appropriately.

[0065] Operation of the vehicle with power assist unit of the present embodiment will be described below referring to FIG. 10.

[0066] FIG. 10 is a flowchart showing the operation of the vehicle with power assist unit shown in FIG. 9.

[0067] As shown in FIG. 10, the human drive power detection unit 5 outputs the detected human drive force, the acceleration detection unit 6 outputs the detected acceleration, and the inclination angle detection unit 13 outputs the detected inclination angle to the assist ratio determination unit 14 (step S10).

[0068] Next, Just as in the case of the second embodiment, on the basis of the human drive force from the human drive power detection unit 5, the assist ratio determination unit 14 selects one of the preset value including the initial value, the value at the present tile and the value calculated responding with the detected current human drive force, and determines the selected value as the first assist ratio (step S8). After this, on the basis of the determined first assist ratio, the acceleration α_1 from the acceleration detection unit 6 and the inclination angle θ from the inclination angle detection unit 13, the assist ratio determination unit 14 calculates the second assist ratio q, and determines the second assist ratio q as the new assist ratio Q.

[0069] As described above, in the vehicle with power assist unit and the controlling method for the same of the present embodiment, the assist ratio determination unit 14 estimates the current running environment on the basis of the human drive force Fh from the human drive power detection unit 5, the acceleration α_1 from the acceleration detection unit 6 and the inclination angle θ from the inclination angle detection unit 13, and determines the assist ratio. With this configuration of the vehicle with power assist unit and the controlling method for the same of the present embodiment, it is possible to determine the assist ratio suited for the running environment responding with the change of the running resistances. As a result, the vehicle can be driven appropriately.

[0070] Although the present invention has been described in terms of the presently preferred embodiments, it is to be understood that such disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art to which the present invention pertains, after having read the above disclosure. Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the true spirit and scope of the invention.

Claims

1. A vehicle with a power assist unit including a vehicle running unit for running said vehicle, a human drive unit for supplying a human drive power to said vehicle running unit and an assist power drive unit for supplying assist power to said vehicle running unit, comprising:

   a human drive power detection unit for detecting a human drive force,
   an acceleration detection unit for detecting the speed and the acceleration of said vehicle,
   a reference environment setting unit for presetting various reference parameters in a reference environment wherein said vehicle runs,
   an acceleration calculation unit in said reference environment for calculating an acceleration in said reference environment in the case where said vehicle runs in said reference environment on the basis of said human drive force from said human drive power detection unit, said speed from said acceleration detection unit and said parameters in said reference environment from said reference environment setting unit, and
   an assist ratio determination unit for determining the assist ratio of said assist power drive unit to said human drive unit on the basis of said acceleration from said acceleration detection unit and said acceleration in said reference environment from said acceleration calculation unit.

2. A vehicle with a power assist unit in accordance with claim 1, wherein said acceleration calculation unit calculates said acceleration in said reference environment by using an equation of motion for said vehicle.

3. A vehicle with a power assist unit in accordance with claim 2, wherein said equation of motion for said vehicle is represented by:

$$m \times \alpha + d \times V + m \times g \times \sin\theta = Fh + Q \times Fh$$

wherein m is the overall weight of said vehicle, α is the acceleration of said vehicle, V is the speed of said vehicle, d is running resistances exerted on said vehicle, g is the gravitational acceleration exerted on said vehicle, θ is the inclination angle of a road surface on which said vehicle is running, Fh is a human drive force and Q is an

assist ratio.

4. A vehicle with a power assist unit including a vehicle running unit for running said vehicle, a human drive unit for supplying a human drive power to said vehicle running unit and an assist power drive unit for supplying assist power to said vehicle running unit, comprising:

a human drive power detection unit for detecting a human drive force,
an acceleration detection unit for detecting the acceleration of said vehicle, and
an assist ratio determination unit for determining the assist ratio of said assist power drive unit to said human drive unit on the basis of said human drive force from said human drive power detection unit and said acceleration from said acceleration detection unit.

5. A vehicle with a power assist unit including a vehicle running unit for running said vehicle, a human drive unit for supplying a human drive power to said vehicle running unit and on assist power drive unit for supplying assist power to said vehicle running unit, comprising:

a human drive power detection unit for detecting a human drive force,
an acceleration detection unit for detecting the acceleration of said vehicle,
an inclination angle detection unit for detecting the inclination angle of a road surface on which said vehicle is running, and
an assist ratio determination unit for determining the assist ratio of said assist power drive unit to said human drive unit on the basis of said human drive force from said human drive power detection unit, said acceleration from said acceleration detection unit and said inclination angle from said inclination angle detection unit.

6. A method of controlling a vehicle with power assist unit including a vehicle running unit for running said vehicle, a human drive unit for supplying a human drive power to said vehicle running unit and an assist power drive unit for supplying assist power to said vehicle running unit, comprising:

a detection step for detecting the speed and the acceleration of said vehicle, and a human drive force supplied to said vehicle running unit,
an acceleration calculation step for calculating an acceleration in a reference environment in the case where said vehicle runs in said reference environment on the basis of said speed and said human drive force detected in said detection step, and preset various reference parameters for said reference environment, and
a determination step for determining the assist ratio of said assist power drive unit to said human drive unit on the basis of said acceleration detected in said detection step and said acceleration in said reference environment calculated in said acceleration calculation step.

7. A method of controlling a vehicle with power assist unit in accordance with claim 6, wherein said acceleration in said reference environment is calculated by using an equation of motion for said vehicle in said acceleration calculation step.

8. A method of controlling a vehicle with power assist unit in accordance with claim 7, wherein said equation of motion for said vehicle is represented by:

$$m \times \alpha + d \times V + m \times g \times \sin\theta = Fh + Q \times Fh$$

wherein m is the overall weight of said vehicle, α is the acceleration of said vehicle, V is the speed of said vehicle, d is running resistances exerted on said vehicle, g is the gravitational acceleration exerted on said vehicle, θ is the inclination angle of a road surface on which said vehicle is running, Fh is a human drive force, and Q is an assist ratio.

9. A method of controlling a vehicle with power assist unit including a vehicle running unit for running said vehicle, a human drive unit for supplying a human drive power to said vehicle running unit and an assist power drive unit for supplying assist power to said vehicle running unit, comprising:

a detection step for detecting the acceleration of said vehicle and a human drive force supplied to said vehicle running unit, and

a determination step for determining the assist ratio of said assist power drive unit to said human drive unit on the basis of said acceleration and said human drive force detected in said detection step.

10. A method of controlling a vehicle with power assist unit including a vehicle running unit for running said vehicle, a human drive unit for supplying a human drive power to said vehicle running unit and an assist power drive unit for supplying assist power to said vehicle running unit, comprising:

a detection step for detecting the acceleration of said vehicle, a human drive force supplied to said vehicle running unit and the inclination angle of a road surface on which said vehicle is running, and
a determination step for determining the assist ratio of said assist power drive unit to said human drive unit on the basis of said acceleration, said human drive force and said inclination angle detected in said detection step.

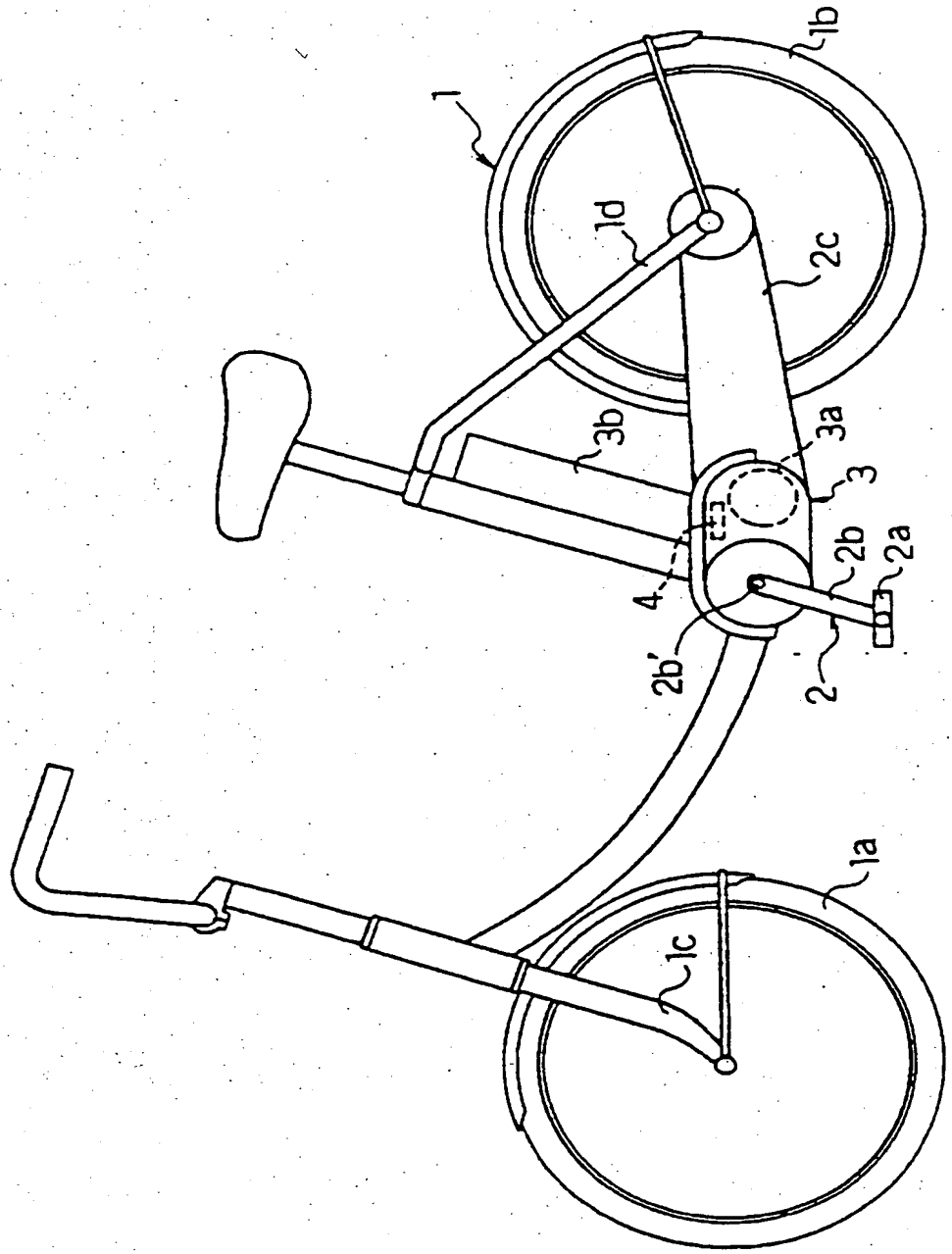


FIG. 1

FIG. 2

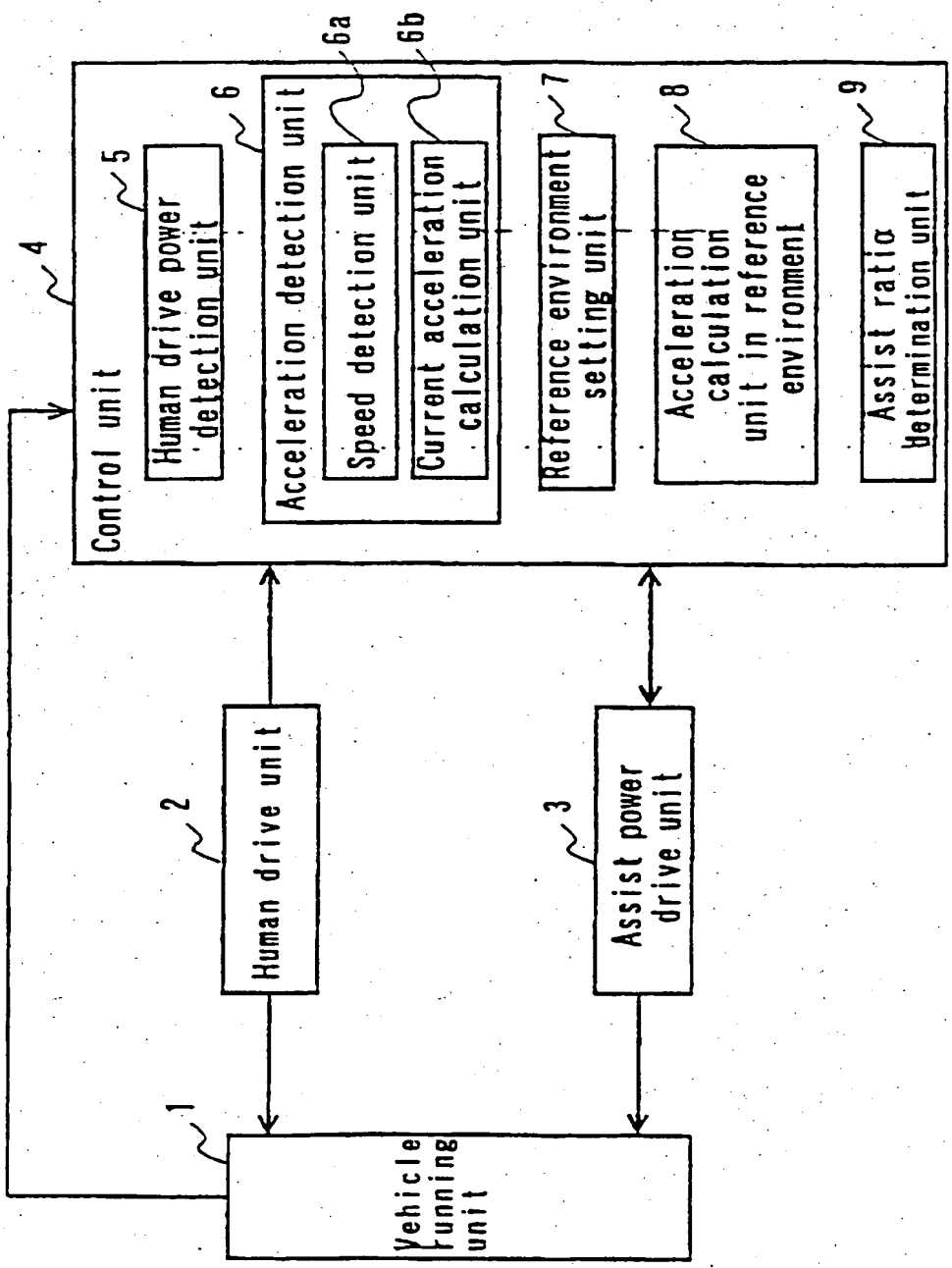

Control unit
4
Human drive power detection unit
5
Acceleration detection unit
6
6a
Speed detection unit
6b
Current acceleration calculation unit
Reference environment setting unit
7
Acceleration calculation unit in reference environment
8
Assist ratio determination unit
9
Human drive unit
2
Assist power drive unit
3
Vehicle running unit
1

FIG. 3

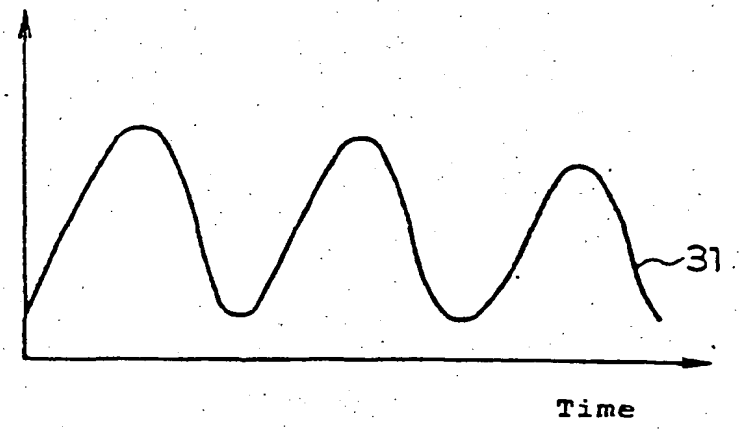

Human drive force
31
Time

FIG. 4

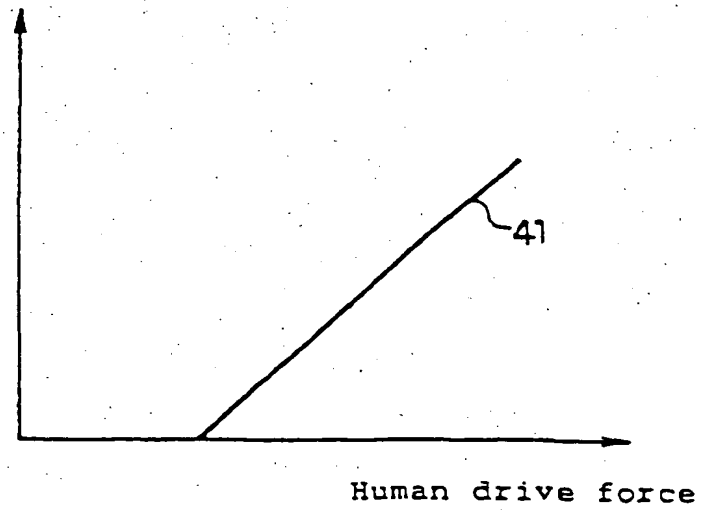

Acceleration in the reference environment
41
Human drive force

FIG. 5

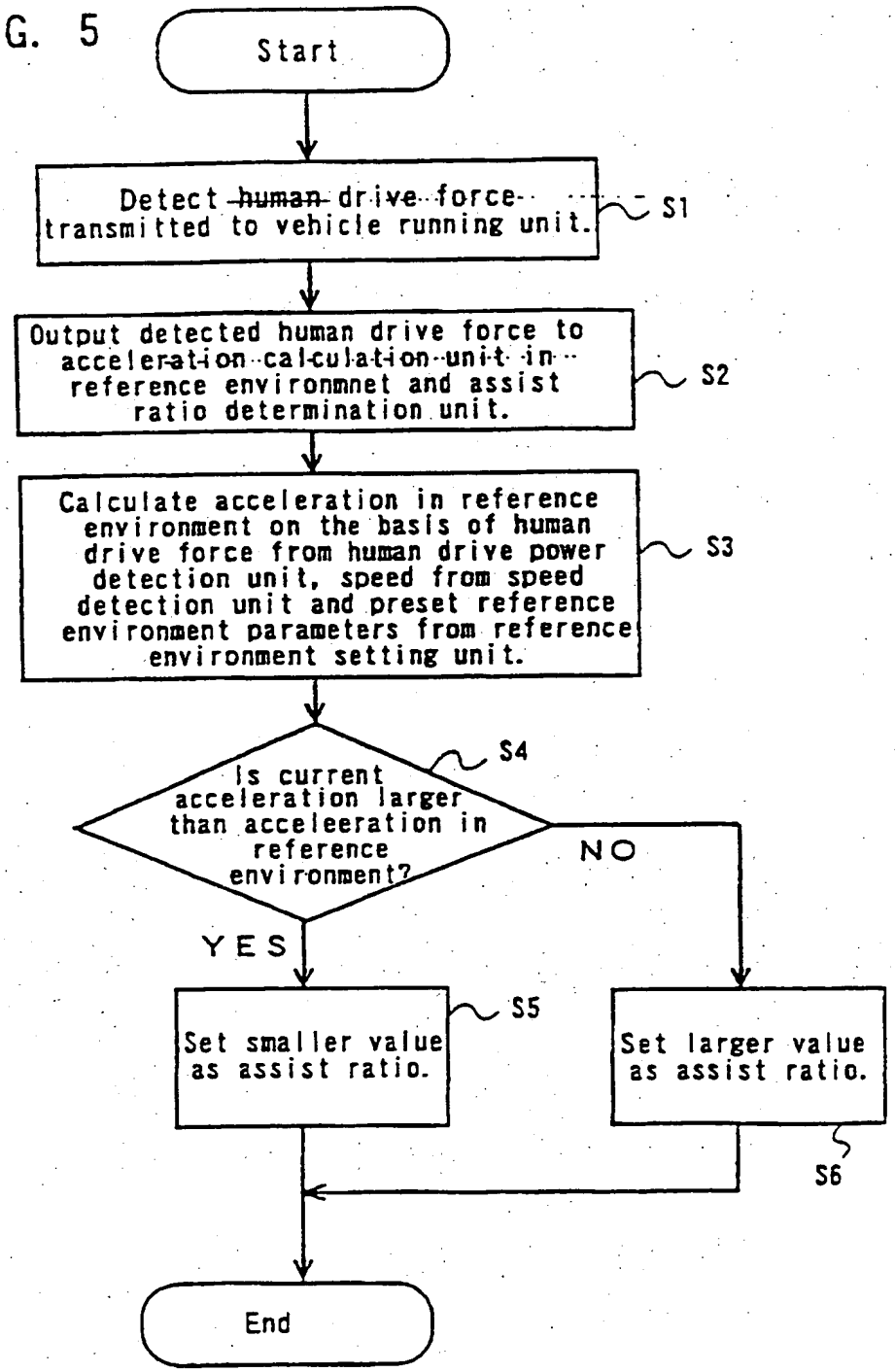

Start
Detect human drive force transmitted to vehicle running unit.
S1
Output detected human drive force to acceleration calculation unit in reference environmnet and assist ratio determination unit.
S2
Calculate acceleration in reference environment on the basis of human drive force from human drive power detection unit, speed from speed detection unit and preset reference environment parameters from reference environment setting unit.
S3
Is current acceleration larger than acceleeration in reference environment?
S4
NO
YES
Set smaller value as assist ratio.
S5
Set larger value as assist ratio.
S6
End

FIG. 6

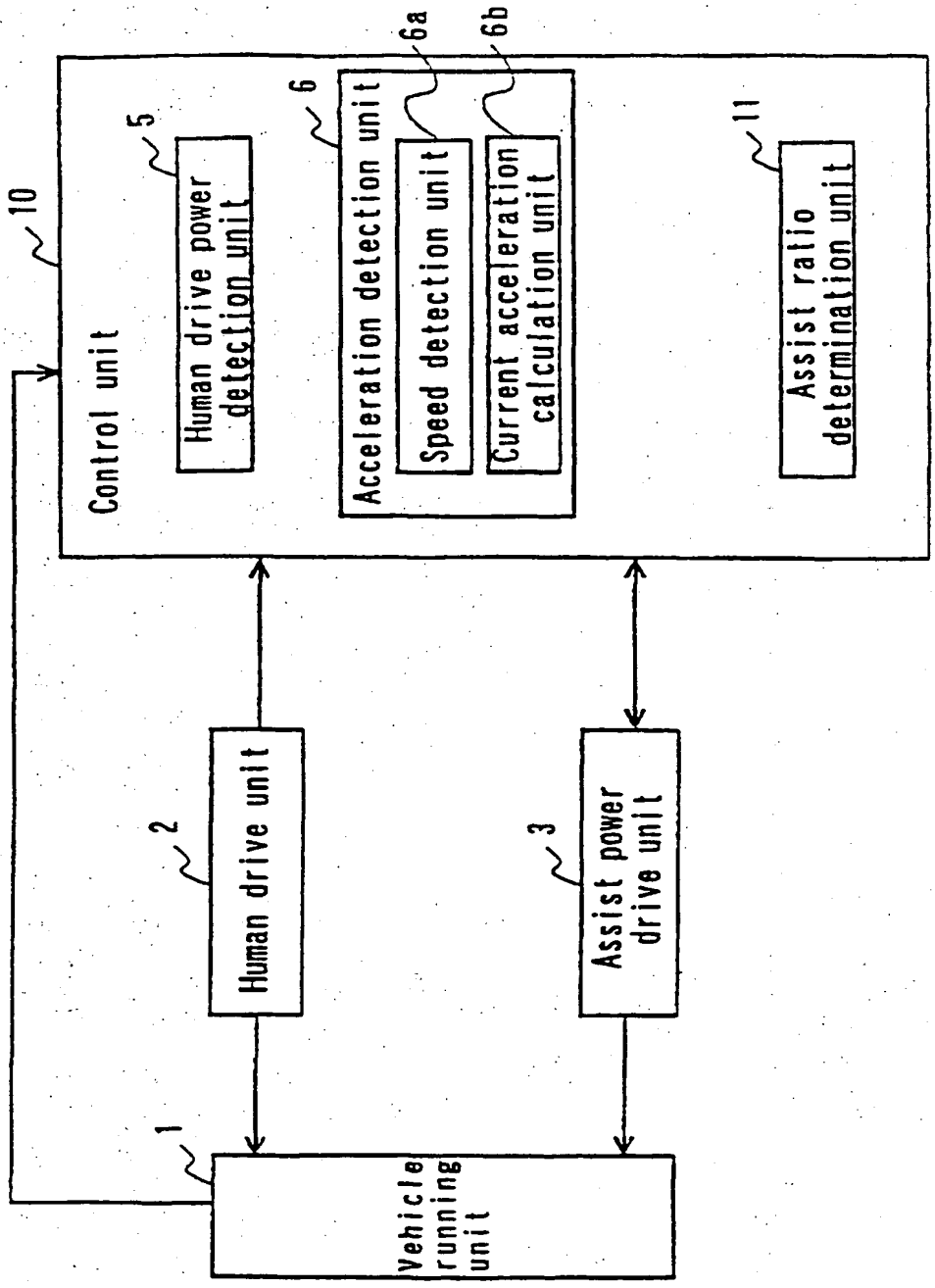

10
Control unit
5
Human drive power detection unit
6
Acceleration detection unit
6a
Speed detection unit
6b
Current acceleration calculation unit
11
Assist ratio determination unit
2
Human drive unit
3
Assist power drive unit
1
Vehicle running unit

FIG. 7

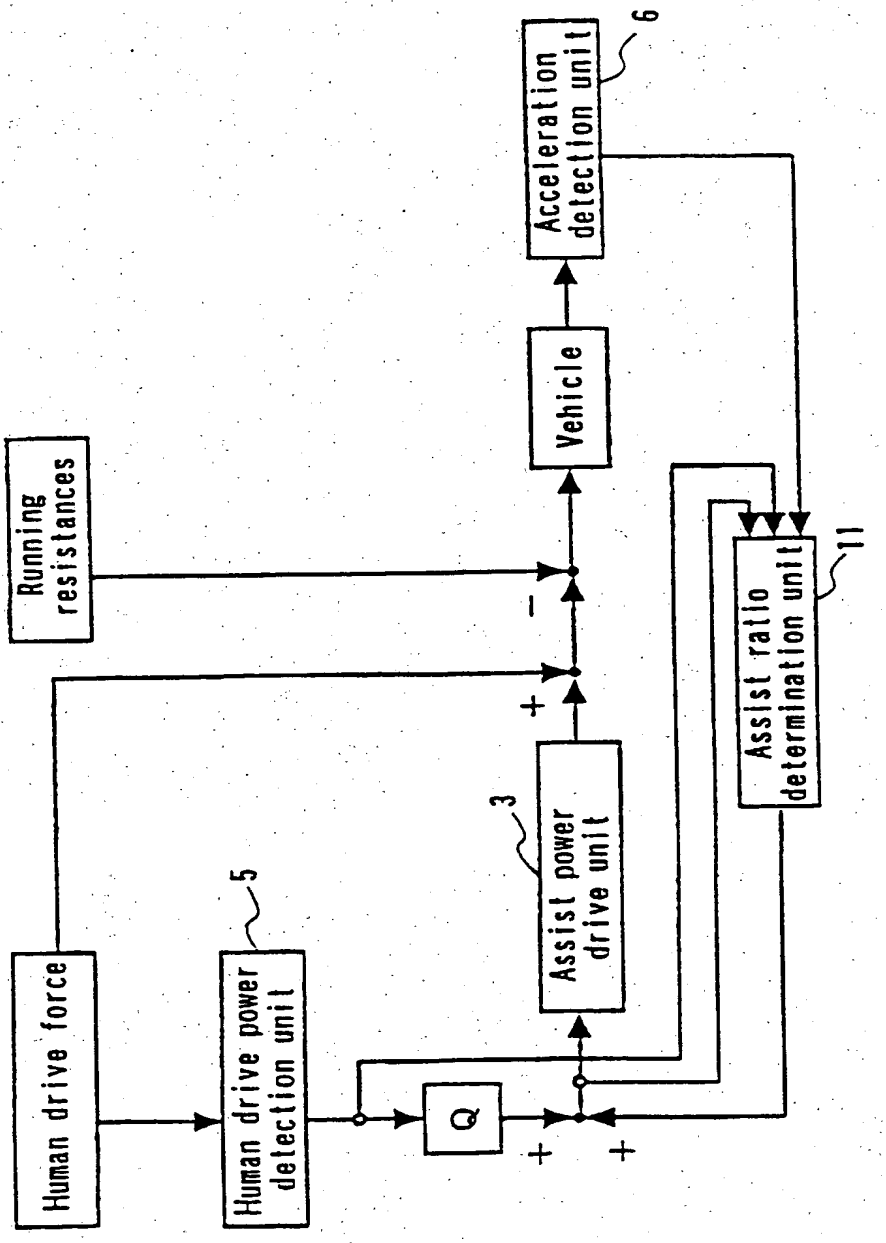

Human drive force
Human drive power detection unit
5
Q
Assist power drive unit
3
Running resistances
Vehicle
Acceleration detection unit
6
Assist ratio determination unit
11
+
+
+
−

FIG. 8

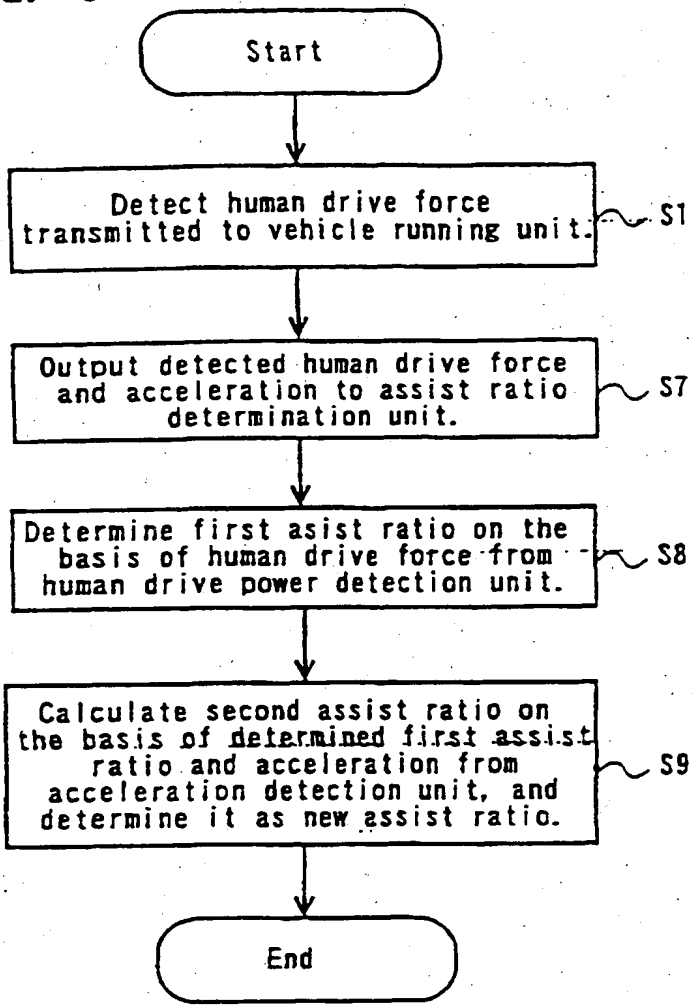

Start
Detect human drive force transmitted to vehicle running unit.
S1
Output detected human drive force and acceleration to assist ratio determination unit.
S7
Determine first asist ratio on the basis of human drive force from human drive power detection unit.
S8
Calculate second assist ratio on the basis of determined first assist ratio and acceleration from acceleration detection unit, and determine it as new assist ratio.
S9
End

FIG. 9

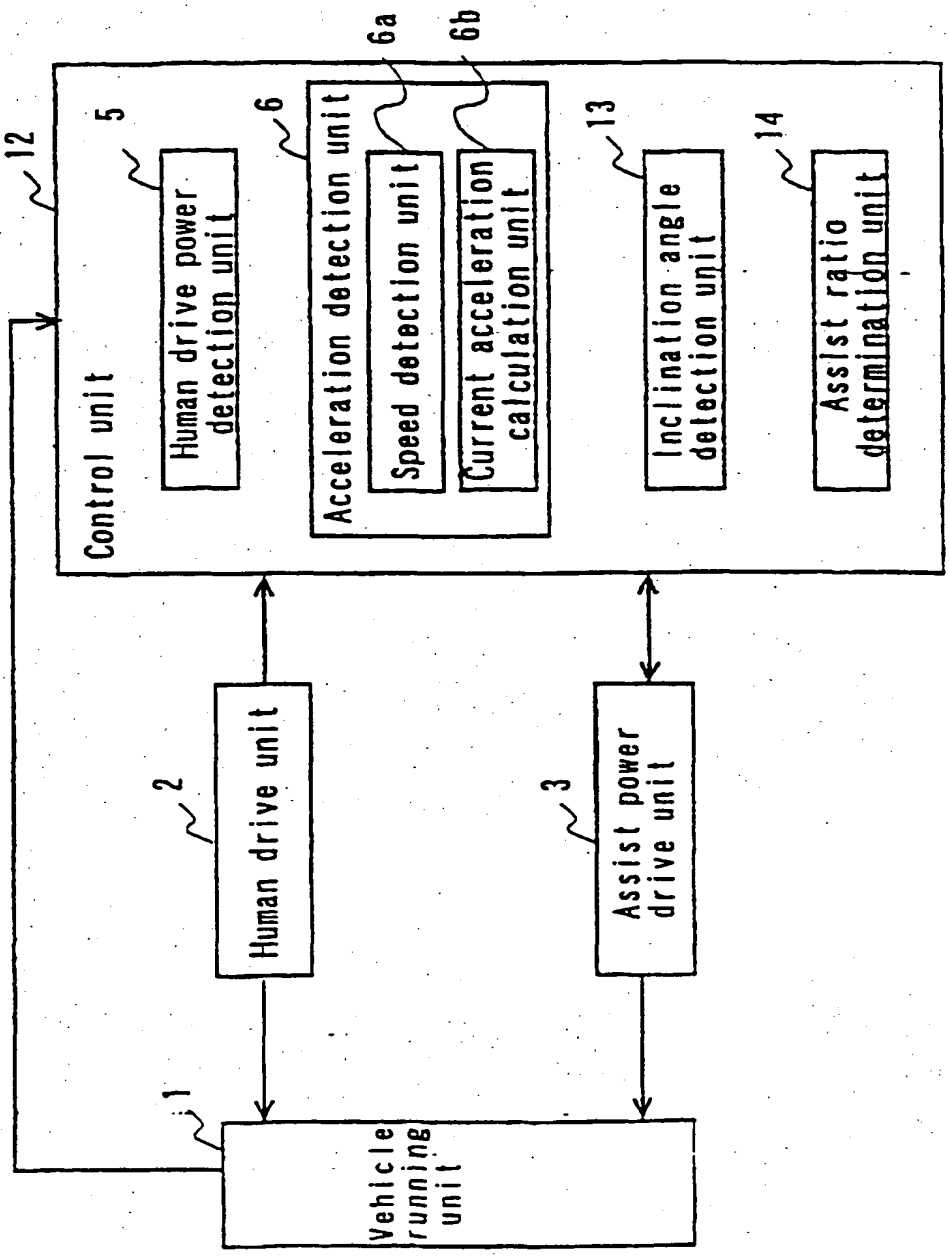
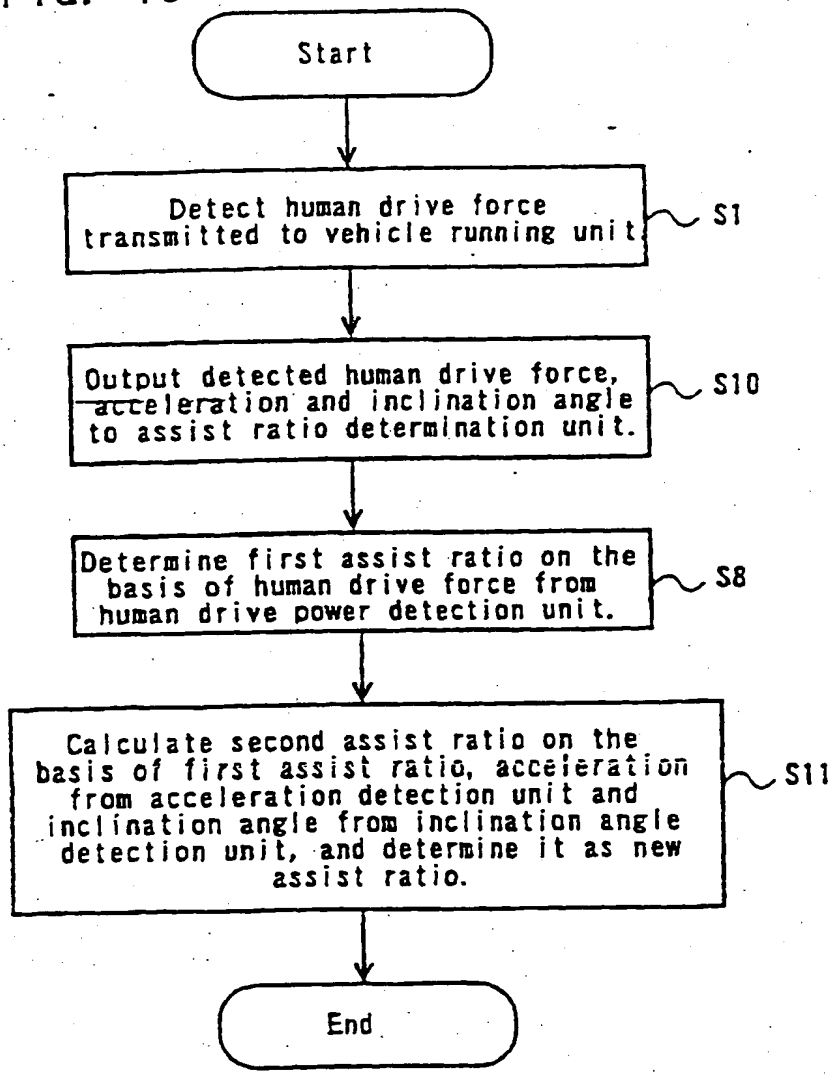

12
Control unit
5
Human drive power detection unit
6
Acceleration detection unit
6a
Speed detection unit
6b
Current acceleration calculation unit
13
Inclination angle detection unit
14
Assist ratio determination unit
2
Human drive unit
3
Assist power drive unit
1
Vehicle running unit

FIG. 10


Start
Detect human drive force transmitted to vehicle running unit
S1
Output detected human drive force, acceleration and inclination angle to assist ratio determination unit.
S10
Determine first assist ratio on the basis of human drive force from human drive power detection unit.
S8
Calculate second assist ratio on the basis of first assist ratio, acceleration from acceleration detection unit and inclination angle from inclination angle detection unit, and determine it as new assist ratio.
S11
End

D1

(19) Europäisches Patentamt
European Patent Office
Office européen d s br vets

(11) EP 0 926 059 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
21.03.2001 Bulletin 2001/12

(43) Date of publication A2:
30.06.1999 Bulletin 1999/26

(21) Application number: 98310636.0

(22) Date of filing: 23.12.1998

(51) Int. Cl.[7]: B62M 23/02

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 24.12.1997 JP 35442997
28.05.1998 JP 14715098

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(54) Vehicle with power assist unit and controlling method therefor

(57) In a vehicle (1) with power assist unit (3) and a controlling method for the same of the present invention, an acceleration calculation unit (8) calculates an acceleration in a reference environment in the case where the vehicle runs in the reference environment on the basis of a human drive force from a human drive power detection unit, a speed from a speed detection unit (6a), and preset various reference parameters in the reference environment from a reference environment setting unit. Furthermore, an assist ratio determination unit compares the current acceleration with the acceleration in the reference environment supplied from the acceleration calculation unit and then determines an assist ratio on the basis of the result of the comparison.

FIG. 1

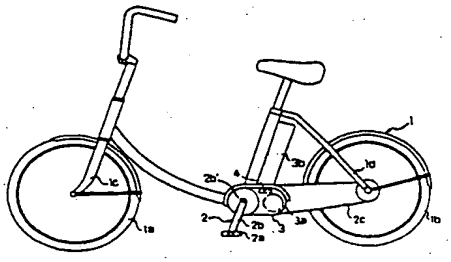
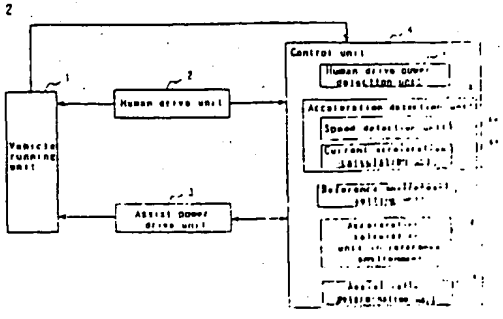


FIG. 2



EP 0 926 059 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 98 31 0636

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 6)
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A	DE 196 01 194 A (GEBLER DIRK ;STAMM MICHAEL (DE)) 24 July 1997 (1997-07-24) * abstract * * column 3, line 53 - line 58 *	1,4-6,9, 10	
A	EP 0 706 909 A (SELIN SISTEMI SRL) 17 April 1996 (1996-04-17) * column 6, line 3 - line 20 *	1,4-6,9, 10	
D,A	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 08, 30 August 1996 (1996-08-30) & JP 08 099683 A (SUZUKI MOTOR CORP), 16 April 1996 (1996-04-16) * abstract *	1,4-6,9, 10	

TECHNICAL FIELDS SEARCHED (Int Cl 6)

B62M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 January 2001	Cauderlier

CATEGORY OF CITED DOCUMENTS

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EP 98 [illegible]

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European [illegible]. The members are as contained in the European Patent Office EDP file on
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